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Physico-chemical and sensory properties of *pupuru* and *pupuru* analogues from co-fermented cassava (*Manihot esculenta Crantz*) and breadfruit (*Artocarpus altilis*) blends

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Abstract. The physico-chemical and sensory qualities of *pupuru* analogues produced from co-fermented cassava and breadfruit blends were investigated. Cassava and breadfruit were processed separately and co-fermented at different proportions to produce *pupuru* and *pupuru* analogues. Seven different samples were produced with the ratios of 100:0, 90:10, 80:20, 50:50, 20:80, 10:90, and 0:100 cassava:breadfruit respectively. The proximate composition, bulk density, hydrogen cyanide, pH, TTA, and sensory properties of the sample were determined using standard methods. The results showed that the protein (2.86–6.41%), fat (0.43–2.05%), ash (0.36–1.17%), crude fibre (0.68–2.83%), and energy values (393.84 to 399.38 kcal/100 g) increased together with breadfruit substitution. The bulk density, pH, total titratable acidity, and hydrogen cyanide content of the sample was in the ranges of 0.47–0.60 g/ml,

Keywords and phrases: bulk density, co-fermented, hydrogen cyanide, proximate composition, sensory properties

4.30–5.30, 0.18–0.31%, and 0.56–1.68 mg/100 g respectively. The *pupuru* analogues had lower hydrogen cyanide content than *pupuru*. The *pupuru* analogues up to 50% breadfruit substitutions had acceptable sensory attributes, comparable to *pupuru*. The study concluded that *pupuru* analogues of acceptable quality can be produced from co-fermented cassava and breadfruit; this entails increasing the utilization of breadfruit.

1 Introduction

Breadfruit (*Altocarpus altilis*) is a crop native to Malaysia and countries of the South Pacific and Caribbean (*Ajani et al.*, 2012). Other botanical names by which the plant is known include *Artocarpus communis* and *Artocarpus incise*. It is widely cultivated to an appreciable extent in the south-western states of Nigeria (*Adejuyitan et al.*, 2018). The present level of breadfruit production in south-western Nigeria has been estimated at about 10 million tonnes of dry weight per year, with potential to exceed 100 million tonnes every year (NTBG, 2009; *Ajani et al.*, 2016). This starchy fruit is sometimes round or oval in shape, with rough green skin, having pale yellow or white flesh. The fruit is high in carbohydrate, low in fat, protein, and is a good source of minerals (iron), vitamins, especially niacin, riboflavin, and pro-vitamin A (*Ajatta et al.*, 2016). However, the traditional use of breadfruit is limited to boiled and pounded breadfruit among the "Ifes", but its use can be expanded by exploring other value-added products in this regard.

Fermentation is one method of processing cassava into another food form, which not only improves the flavour and taste of the product but extends its shelf life *(Falade & Akingbala*, 2010). Acid production during cassava fermentation has been attributed to the activities of lactic acid bacteria on the carbohydrate content of cassava tuber (*Oyewole & Afolami*, 2001). Fermentation enhances the reduction of the cyanide level and detoxification of the root (*Kostinek et al.*, 2005). One of the notable products from fermented cassava is *pupuru*.

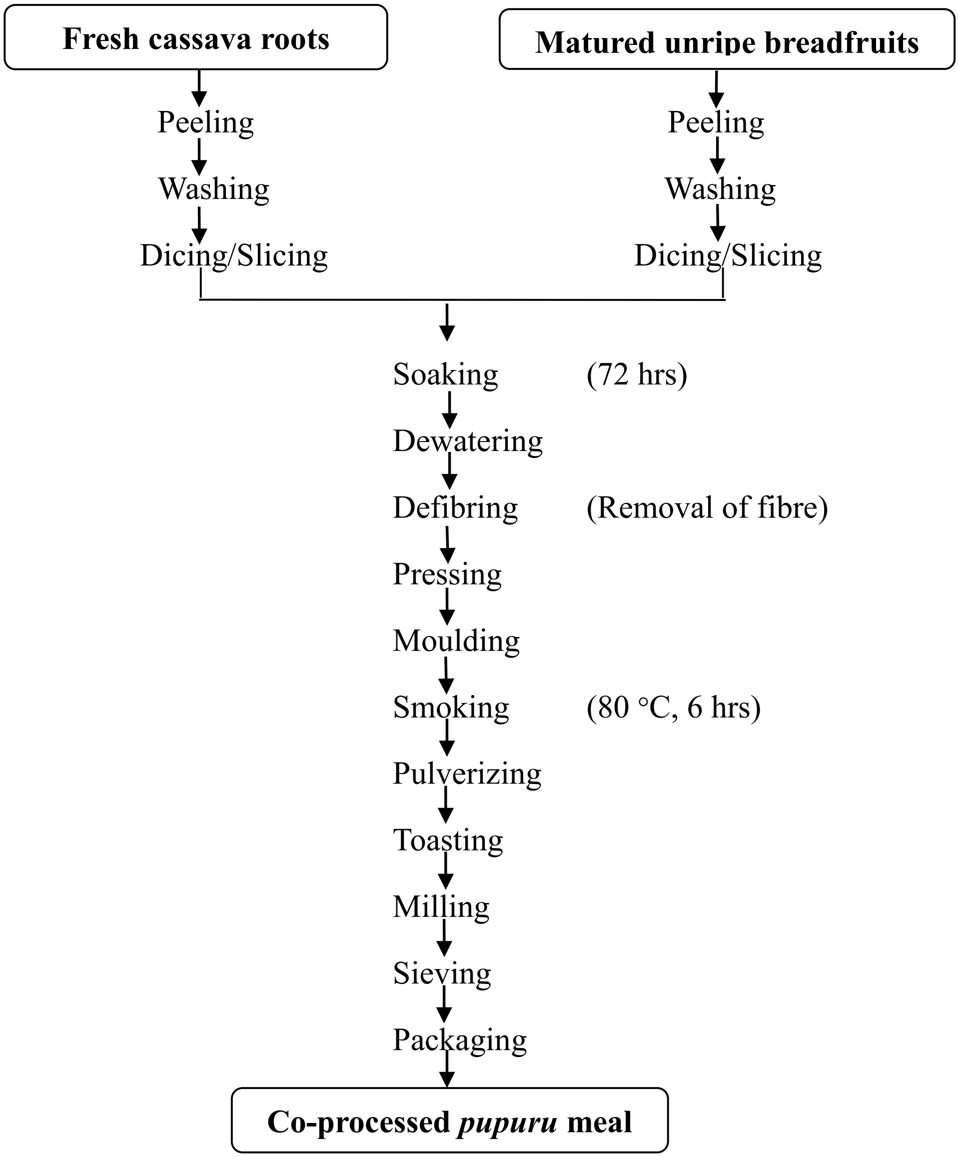
Pupuru, a fermented cassava product, is usually consumed by the people living in the riverine areas of the southern and middle belts of Nigeria, where it is also known as "Ikwurikwu" (*Shittu et al.*, 2003; *Daramola et al.*, 2010). Pupuru and other cassava products are widely accepted and consumed in Nigeria (*Adejuyitan et al.*, 2018). It is moulded into the shape of a smoke ball, which is usually made into dough in boiling water before consumption with any desired soup (*Ikujenlola & Lawson*, 2005). Breadfruit is nutritious, cheap, and available in high abundance during its season, while it also helps out the poor people in rural areas, providing them with an extra layer of food security (*Omobuwajo*, 2003). The expansion of breadfruit utilization has not been extended to the production of *pupuru analogue*. However, the putrid smell has limited its sensory acceptability, and there is also need for a further investigation into the physico-chemical properties of *pupuru* analogues to increase the utilization of breadfruit and make it a food of first choice, especially in several food deficit regions and countries. Hence, the objectives of this study were to produce *pupuru* analogue from co-fermented breadfruit and cassava blends and to evaluate the physico-chemical and sensory properties in a culturally familiar form, analogous to *pupuru* from cassava.

2 Materials and methods

Matured unripe breadfruits (*Artocarpus altilis*) and matured cassava root (*Manihot esculenta*) were purchased at Ilode and Tonkere markets in Osun State, Nigeria.

Production of *pupuru* and *pupuru* analogue meals

Cassava tuber and matured unripe breadfruits were washed and peeled. The cassava and breadfruit were mixed at different ratios of 100:0, 90:10, 80:20, 50:50, 20:80, 10:90, and 0:100 (wt/wt). It was sliced into easy-to-manage pieces using dicing machine. This is to ensure regular shape and size; this will guarantee the uniform fermentation of the diced pieces. The diced/sliced breadfruit and cassava roots were co-fermented (this is to allow for synergy in the fermentation process of the two biomaterials) in water (1:3 solid:water) inside a plastic container for 72 hrs at ambient temperature (28–32 °C) to allow the inherent fermenting microorganisms to act on it and soften the pieces. The fermented mash was drained of excess water and the fibres were removed manually. Thereafter, the mash was packed inside bags and pressed using hydraulic press for 30 minutes to further reduce the water. The dewatered mash was moulded into balls of 5–10 cm in diameter. The moulded balls were smoked in the kiln dryer at 80 °C for 6 hrs. In order to produce meal from the smoked balls, they were scraped of the dark outer portion of the balls, pulverized, sieved, and toasted ($> 90\,^{\circ}$C) for 10 min in a traditional toaster. The toasted mass was cooled, re-milled, sieved (630 micron sieve), and packaged to obtain *pupuru* and *pupuru* analogue meals (*Figure 1*) (*Ikujenlola & Lawson*, 2005).



Source: *Ikujenlola & Lawson* (2005)

Figure 1. Production of *pupuru* and *pupuru* analogue meals

Formulation of samples

Table 1 shows the various *pupuru* and *pupuru* analogues produced from cassava and co-fermented cassava and breadfruit respectively.

Chemical analysis

The proximate compositions of the samples were determined using standard methods of AOAC (2010). The samples were analysed for moisture, ash, crude fibre, crude protein, crude fat, and carbohydrate. Calories was calculated using Atwater factors; the sum of 4 × percentage of Protein, 4 × percentage of carbohydrate, and 9 × percentage of fat (*Onoja et al.*, 2014).

Table 1. Formulation of *pupuru* and *pupuru* analogues from co-processed cassava and breadfruit

Samples	Cassava	Breadfruit
100% PF	100	–
100% BP	–	100
90:10 PF/BP	90	10
80:20 PF/BP	80	20
50:50 PF/BP	50	50
20:80 PF/BP	20	80
10:90 PF/BP	10	90

Source: *Ikujenlola & Lawson* (*2005*)

Keys: **100% PF** – 100% cassava; **100% BP** – 100% breadfruits; **90:10 PF/BP** – 90% cassava co-processed with 10% breadfruits; **80:20 PF/BP** – 80% cassava co-processed with 20% breadfruits; **50:50 PF/BP** – 50% cassava co-processed with 50% breadfruits; **20:80 PF/BP** – 20% cassava co-processed with 80% breadfruits; **10:90 PF/BP** – 10% cassava co-processed with 90% breadfruits

Physico-chemical properties

Bulk density

The bulk density was determined by the method of *Okezie* & *Bello* (1988). A 10 ml graduated cylinder, previously tared, was gently filled with the sample. The bottom of the cylinder was gently tapped on a laboratory bench several times until there was no further diminution of the sample level after filling to the 10 ml mark. Bulk density was calculated as weight of sample per unit volume of sample (g/ml).

pH

The pH was measured by making a 10% w/v suspension of the sample in distilled water. The suspension was mixed thoroughly in a Sorex blender and the pH was measured with a Hanna checker pH meter (Model HI1270).

Total titratable acidity

The total titratable acidity of the sample was determined using the method described by AOAC (2010). Five grams of the sample was weighed in a clean beaker and 50 ml of distilled water was added and homogenized, from which 25 ml of the solution was taken into another conical flask, and three drops of 2% phenolphthalein indicator was added. The mixture was titrated against 0.1 N sodium hydroxide (NaOH) until a permanent pink-coloured end-product was obtained. Total titratable acidity was calculated as follows and expressed as percentage lactic acid.

$$\%\ \text{lacid acid (wt/vol)} = N \cdot V \cdot Eq.wt \cdot W \cdot 1000 \cdot 100, \tag{1}$$

where: N = normality of titrant, usually NaOH (mEq/ml); V = volume of titrant (ml); $Eq.wt$ = equivalent weight of predominant acid (mg/mEq); W = mass of sample (g); 1000 = factor relating mg to gram (mg/g) (1/1000).

Hydrogen cyanide determination

The cyanogenic potentials of *pupuru* meals were determined using the picrate paper kits method as described by *Bradburg et al.* (1999). One gram sample of *pupuru* meal was homogenized in a 250 ml conical flask containing 25 ml of water. A strip of spot paper soaked in an alkaline sodium picrate solution was fixed in the solution with the cork; the flask was kept for 18 hrs at 27 °C (room temperature), the strip was removed and later eluted in 60 ml, and the absorbance was read at 540 nm using a spectrophotometer. The hydrogen cyanide content was extrapolated using a cyanide standard curve.

Sensory evaluation

A voluntary panel of 15 judges made up of both males and females were selected from Obafemi Awolowo University, Ile-Ife. The selection was based on the fact that they were familiar with *pupuru*. The samples were placed on white plates coded with alphabetic letters under normal lighting condition at room temperature. Panellists were instructed in assessment terminology and requested to evaluate the various *pupuru* and *pupuru analogue* samples for taste, colour, aroma, texture, mouldability, and overall acceptability using a 9-point Hedonic scale as follows: 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, and 9 = like extremely (*Iwe*, 2002).

Statistical analysis

The data obtained were expressed as mean ± standard deviation of nine experiments and were subjected to statistical analysis using one-way analysis of variance to determine the significant differences between means with significance level taken at $\alpha = 0.05$. Tukey's least significant difference test was used to compare the means. All statistical procedures were carried out using SPSS version 17.0 (SPSS, Chicago, IL, USA).

3 Results and discussion

Physical appearance and proximate composition of *pupuru* and *pupuru* analogues

The *pupuru* and *pupuru* analogue meals produced from cassava and breadfruit, respectively, are presented in *Figure 2.* It was observed that *pupuru* had a brighter white colour compared to *pupuru* analogues, which are creamy in colour. The higher the proportion of breadfruit is, the darker the colour. The locally produced *pupuru* and industrial *pupuru* were of brighter colour.

The results of the proximate compositions of *pupuru* and *pupuru* analogues from cassava and cassava co-processed with breadfruit, respectively, are presented in *Table 2.* The protein content of all the *pupuru* analogues ranged between 2.86 and 6.41%. It was observed that the protein content of *pupuru* analogues from 100% breadfruit was 6.41%, which was the highest of all the samples. The protein content of *pupuru* from 100% cassava was higher than 0.55% as reported by *Ojo et al.* (2017) for 100% cassava starch obtained from cassava starch-mushroom flour blends. It was observed that the protein content increased with increase in the level of substitution of breadfruit. The protein obtained was comparable with the range of 1.52–7.22% reported by *Alozie et al.* (2017) for gari fortified with soybeans, melon seed, and moringa seed flours. However, it was higher than the range (1.70–3.75%) reported by

Adejuyitan et al. (2018) for *pupuru* from breadfruit and tigernut flour. There was no significant difference ($p > 0.05$) in the protein content of 100% BP and 10:90 PF/BP. *Padmaja & Jisha* (2005) reported that the protein content of cassava-based composite flours increased with the incorporation of legume flours.

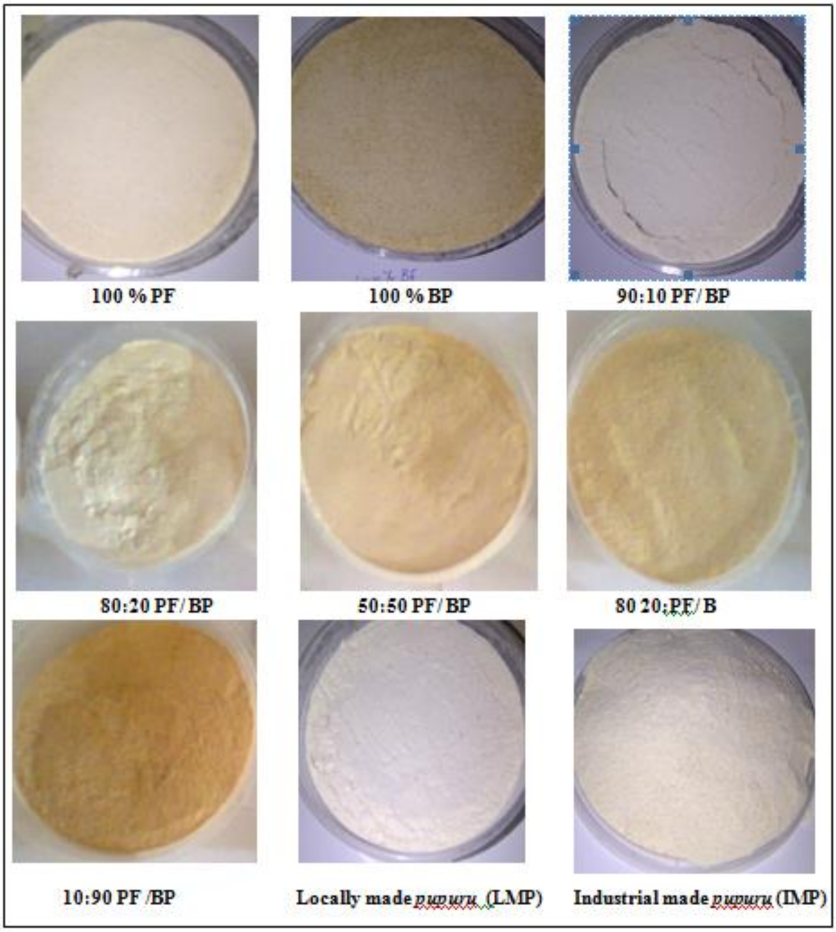


Figure 2. Finished products of *pupuru* and *pupuru* analogue meals

Keys: **100% PF** – 100% cassava; **100% BP** – 100% breadfruits; **90:10 PF/BP** – 90% cassava co-processed with 10% breadfruits; **80:20 PF/B**P – 80% cassava co-processed with 20% breadfruits; **50:50 PF/BP** – 50% cassava co-processed with 50% breadfruits; **20:80 PF/BP** – 20% cassava co-processed with 80% breadfruits; **10:90 PF/BP** – 10% cassava co-processed with 90% breadfruits

Table 2. Proximate compositions of *pupuru* and *pupuru* analogue meals (% dry basis)

Samples	Moisture	Ash	Fat	Crude fibre	Protein	Carbohydrate	Energy value (kcal/100 g)
100% PF	11.80 ± 0.35^{cd}	1.17 ± 0.22^{a}	0.43 ± 0.07^{g}	0.90 ± 0.00^{c}	2.86 ± 0.19^{e}	94.64 ± 2.08^{ab}	393.84 ± 1.99^{b}
100% BP	12.98 ± 0.02^{a}	1.07 ± 0.07^{a}	2.05 ± 0.17^{a}	2.83 ± 0.23^{a}	6.41 ± 0.18^{a}	87.64 ± 3.77^{c}	394.67 ± 0.85^{c}
90:10 PF/BP	11.47 ± 0.42^{d}	0.36 ± 0.14^{c}	0.70 ± 0.02^{f}	0.68 ± 0.11^{c}	3.33 ± 0.16^{de}	94.93 ± 1.82^{a}	399.38 ± 0.65^{a}
80:20 PF/BP	12.97 ± 0.67^{a}	0.54 ± 0.23^{bc}	0.85 ± 0.02^{e}	0.88 ± 0.06^{c}	3.77 ± 0.41^{cd}	93.96 ± 2.30^{ab}	398.58 ± 1.73^{b}
50:50 PF/BP	12.72 ± 0.14^{ab}	0.59 ± 0.03^{bc}	1.40 ± 0.01^{d}	2.32 ± 0.17^{b}	4.26 ± 0.37^{c}	91.43 ± 2.37^{abc}	395.33 ± 0.56^{bc}
20:80 PF/BP	12.73 ± 0.18^{ab}	0.69 ± 0.17^{b}	1.62 ± 0.02^{c}	2.40 ± 0.35^{b}	5.52 ± 0.35^{b}	89.77 ± 3.10^{bc}	395.79 ± 1.30^{bc}
10:90 PF/BP	12.21 ± 0.30^{bc}	1.06 ± 0.13^{a}	1.88 ± 0.01^{b}	2.48 ± 0.17^{b}	5.87 ± 0.19^{ab}	88.71 ± 3.64^{bc}	395.24 ± 3.41^{b}

Mean ± standard deviation of triplicate determinations.

Means with the same superscripts in the same column are not significantly different at 5% probability level.

Keys: **100% PF** – 100% cassava; **100% BP** – 100% breadfruits; **90:10 PF/BP** – 90% cassava co-processed with 10% breadfruits; **80:20 PF/BP** – 80% cassava co-processed with 20% breadfruits; **50:50 PF/BP** – 50% cassava co-processed with 50% breadfruits; **20:80 PF/BP** – 20% cassava co-processed with 80% breadfruits; **10:90 PF/BP** – 10% cassava co-processed with 90% breadfruits

The ash content of the *pupuru* and *pupuru* analogues ranged between 0.36% and 1.17%. The ash content of 100% PF was the highest but was not significantly different ($p < 0.05$) from that of 100% BP and 10:90 PF/BP. The value obtained was lower than the range (1.55–2.47%) recorded by *Alozie et al.* (2017) for gari fortified with soybean, melon seed, and moringa seed flours. The ash content of the *pupuru* analogue from 10% breadfruit (0.36%) was comparable with 0.33% as reported by *Monayajo* & *Nupo* (2011) for *pupuru* fortified with soy flour. However, ash values obtained in this study were lower than the maximum 3% recommended by the Codex Alimentarius Commission (1995) for edible cassava flour.

The fat content of the *pupuru* and *pupuru* analogues ranged from 0.43 to 2.05%. The *pupuru analogue* from 100% breadfruit had the highest fat content (2.05%). 100% PF had the lowest value (0.43%). These values were higher than the range of 0.26–0.56% reported for cassava-African yam bean fufu blends by *Nwokeke et al.* (2013). It was observed that the fat content of *pupuru analogue* from 100% breadfruit was lower than 100% breadfruit *pupuru analogue* (3.25%) as reported by *Adejuyitan et al.* (2018) but higher than the fat content of breadfruit flour (1.09%) reported by *Adepeju et al.* (2011). The increase in the fat content of the products could be attributed to the increase in the substitution level of breadfruit.

Crude fibre contents increased with increase in the level of substitution of breadfruit. The value ranged between 0.68 and 2.83%, with the highest in 100% BP and the lowest value in 90:10 PF/BP. There was no significant difference ($p > 0.05$) between the crude fibre of 100% PF, 90:10 PF/BP and 80:20 PF/BP. However, they were significantly different ($p < 0.05$) from those of 50:50 PF/BP and 20:80 PF/BP. The values were comparable to the crude fibre 1.34–2.01% from cassava-breadfruit fufu by *Agbon et a*l. (2010) but lower than the values (1.38–5.11%) reported by *Adejuyitan et al.* (2018) for *pupuru* flour from breadfruit and tigernut flour. The values in this study were higher than the 2% upper limit specified for edible cassava flour by the Codex Alimentarius Commission (1995). Crude fibre helps in maintaining the normal peristaltic movement of the intestinal tracts, thereby preventing colon diseases such as piles, cancer, or appendicitis (*Famurewa* & *Oluwalana*, 2007).

The moisture content of the *pupuru* and *pupuru* analogues ranged between 11.47 and 12.98%. The moisture content range in this study was lower than the range (12.10–14.00%) reported for three traditional fermented cassava products by *Shittu* & *Adedokun* (2010) but higher than the range (8.79–9.35%) reported by *Ojo et al.* (2017) for cassava starch and mushroom blends. The moisture content of *pupuru* analogues from 50% and 80% breadfruit substitutions were significantly different ($p < 0.05$) from 100% PF. The moisture content of flour products is a function of drying temperature, time, and loading depth (*Ikujenlola* & *Lawson*, 2005). The higher the moisture content of food materials, the lower the shelf stability (*Aluge et al.*, 2016). Generally, the moisture content of the products was within the acceptable levels (10–14%) for flours (*Butt et al.*, 2004).

The values of carbohydrate decreased from 94.93 to 87.64% with increase in the level of substitution of breadfruit. The value of the carbohydrate for 90:10 PF/BP was the highest as compared to other samples. There was no significant difference ($p > 0.05$) between the values of the carbohydrate content for *pupuru* analogues substituted with 80% and 90% breadfruit. However, it was significantly different ($p < 0.05$) from the values obtained for 100% PF and 90:20 PF/BP. The decrease in the carbohydrate content of the analogues could be explained based on the lower level of carbohydrate present in breadfruit (87.64%) compared to cassava (94.93%). This observation agrees with the report of *Agbon et al.* (2010).

The energy value of *pupuru* and *pupuru* analogues ranged between 393.84 and 399.38 kcal/100 g. It was observed that the energy value of *pupuru analogue* substituted with 10% breadfruit had the highest value of 399.38 kcal/100 g. There was no significant difference ($p < 0.05$) between the energy value of *pupuru* analogues from 80% and 90% breadfruit substitution. The energy value of *pupuru* from 100% cassava was higher than the value 363.73 kcal/100 g (100% cassava starch) for cassava starch-mushroom blends (*Ojo et al.*, 2017). However, *Alaba et al.* (2013) reported reduced energy levels (358.03–359.32 kcal/100 g) for cassava flour.

Physico-chemical properties

The bulk density (*Figure 3*) ranged from 0.47 to 0.64 g/ml with a significant difference ($p < 0.05$). 100% BP had the highest value (0.64 g/ml) compared to other samples. There was no significant difference ($p < 0.05$) between the bulk density of 50:50 PF/BP and 20:80 PF/BP. However, those of 10:90 PF/BP and 90:10 PF/BP were the same. The range was comparable to the bulk density (0.40–0.62) reported by *Alaba et al.* (2013) for cassava flour (*pupuru*) but lower than 0.82–0.85 g/ml for composite flours made from wheat, breadfruit, and cassava starch, as reported by *Ajatta et al.* (2016). Bulk density is a measure of heaviness of flour (*Adejuyitan et al.*, 2009), and low bulk density is desired in flour blends as it contributes to lower dietary bulk, ease of packaging and transportation (*Aluge et al.*, 2016).

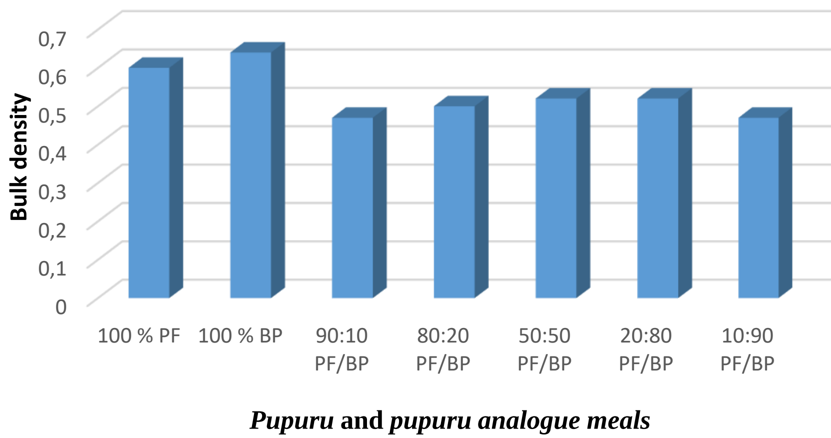


Figure 3. Bulk density (g/ml) of the *pupuru* and *pupuru* analogues

pH values (*Figure 4*) ranged between 4.37 and 5.30. pH value gives a measure of the acidity or alkalinity of the flour. The substitution of cassava in the *pupuru* analogues of breadfruit showed a gradual increase in the pH of the products. This was due to the pH of breadfruit, which was higher than that of cassava. There was no significant difference ($p < 0.05$) between the pH of the *pupuru* 100% PF and of *pupuru* analogues 20:80 PF/BP.

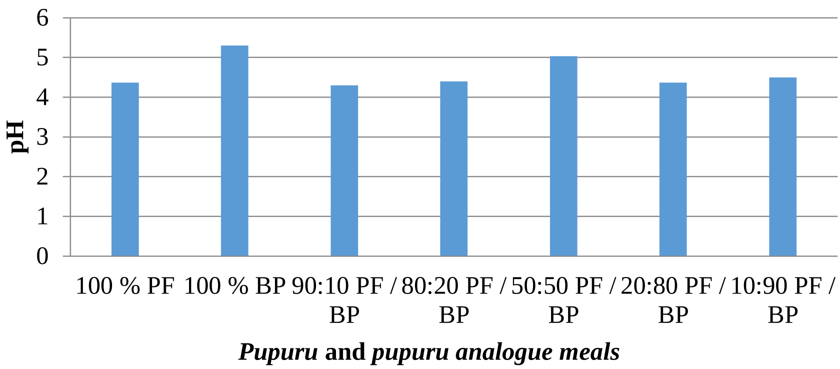


Figure 4. The pH of *pupuru* and *pupuru analogue meals*

The pH value of *pupuru* from 100% cassava (4.37) was lower than the value reported by *Adejuyitan et al.* (2018) for similar products. The pH decreased as a result of secretion of lactic acid, which implies that the more the cassava stays in the water during fermentation, the more there is reduction in the pH by the action of fermenting organisms. Acidic products are more shelf-stable than their non-acidic counterparts (*Caballero et al.*, 2015).

The total titratable acidity (TTA) (*Figure 5*) expressed as percentage lactic acid of *pupuru* samples ranged between 0.18 and 0.31%. There was no significant difference ($p < 0.05$) in the total titratable acidity of all the samples. The value was higher than 0.13–0.16% for cassava flour (*pupuru*) as reported by *Alaba et al.* (2013). TTA values obtained for 100% BP are comparable to the value (0.25%) for 100% breadfruit *pupuru* flour reported by *Adejuyitan et al.* (2018). Titratable acidity gives a measure of the amount of acid present in the food. The level of this index is used to estimate the quality of the flour. These values were in agreement with the Nigerian Industrial Standard recommendation of less than 10 g/100 ml total titratable acidity for gari samples. This shows that the period of fermentation of the various samples was adequate.

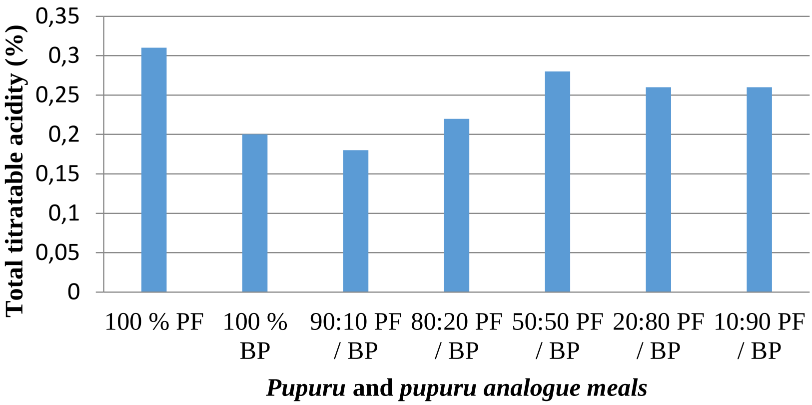


Figure 5. The total titratable acidity of *pupuru* and *pupuru analogue meals*

The cyanide concentration (*Figure 6*) of the *pupuru* samples ranged between 0.56 and 1.68 mg/100 g. The *pupuru* analogues produced from 100% breadfruit had the least cyanide value (0.56 mg/100 g) while those from 100% cassava had the highest (1.68 mg/100 g). The cyanide content decreased as the level of substitution of breadfruit increased. Hydrogen cyanide (HCN) is the predominant antinutrient/toxic substance in cassava tubers and cassava products. The knowledge of cyanogenic glycoside content of food is vital because cyanide, being an effective cytochrome oxidase inhibitor, interferes with the aerobic respiratory system (*Onwuka*, 2005). The level of cyanide (0.42–0.47 mg/100 g) reported by *Alaba et al.* (2013) for cassava flour (*pupuru*) is lower than the values obtained. The reduction in cyanide could be attributed to the synergistic effect of loss by hydrolysis into the steep water during fermentation and toasting (*Irtwange & Achimba*, 2009).

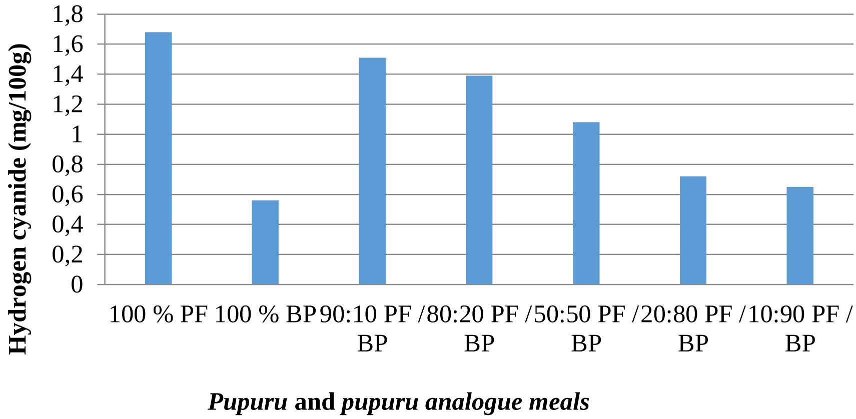


Figure 6. The hydrogen cyanide of *pupuru* and *pupuru analogue meals*

Sensory evaluation

Table 3 shows the results of the sensory evaluation of *pupuru* and *pupuru* analogues. The scores obtained for the colour of *pupuru* and *pupuru* analogues were significantly different ($p < 0.05$) from each other, with 90:10 PF/BP having the most preferred colour (8.6). The scores for colour of locally (LMP) and industrially made *pupuru* (IMP) (7.47 and 7.07 respectively) were significantly different ($p < 0.05$) from the colour of 100% PF (5.40). There was the least preference for 10:90 PF/BP in terms of colour, texture, mouldability, and taste. Pupuru and *pupuru* analogues from 100% PF, 50:50 PF/BF, locally-made *pupuru* (LMP), and 20:80 PF/BP did not differ significantly ($p < 0.05$) in terms of aroma and texture. However, the other samples were significantly different ($p < 0.05$) from industrially-made *pupuru* (IMP). Usually, during smoking, there is a deposition of organic components, such as phenols, alcohols, aldehyde, or ketones, which influences flavour and the antimicrobial effects on the products (*Tewe*, 2004). In the case of mouldability, there was no significant difference ($p > 0.05$) between 100% PF, 100% BP, 50:50 PF/BP, 20:80 PF/BP, and LMP respectively. Of all the samples, the 10% breadfruit substitution was the most acceptable meal. Meanwhile, *pupuru* analogues up to 50% breadfruit substitution had sensory attributes comparable to those of *pupuru* produced locally and industrially.

Table 3. Sensory evaluation of *pupuru* and *pupuru* analogues

Samples	Colour	Aroma	Texture	Mouldability	Taste	Overall acceptability
100% PF	5.40 ± 1.55^{de}	5.73 ± 1.39^{bc}	5.53 ± 0.99^{bc}	5.87 ± 1.36^{bc}	5.60 ± 1.80^{bcd}	6.00 ± 1.36^{bc}
100% BP	4.60 ± 1.92^{ef}	4.47 ± 1.77^{d}	4.67 ± 1.63^{cd}	5.27 ± 2.37^{bc}	4.67 ± 2.19^{de}	5.80 ± 2.24^{cd}
90:10 PF/BP	8.60 ± 0.63^{a}	7.47 ± 1.06^{a}	7.87 ± 0.74^{a}	7.67 ± 0.82^{a}	7.53 ± 1.19^{a}	8.13 ± 0.83^{a}
80:20 PF/BP	6.73 ± 1.10^{cb}	6.60 ± 1.06^{ab}	6.40 ± 1.12^{b}	6.27 ± 1.53^{b}	5.93 ± 2.09^{bcd}	6.53 ± 1.46^{b}
50:50 PF/BP	5.53 ± 1.55^{de}	5.93 ± 1.16^{bc}	5.40 ± 1.18^{bc}	5.53 ± 1.30^{bc}	5.67 ± 1.45^{bcd}	6.00 ± 1.41^{bc}
20:80 PF/BP	6.00 ± 1.25^{cd}	6.20 ± 1.01^{bc}	5.73 ± 1.79^{bc}	5.27 ± 1.75^{bc}	5.20 ± 1.82^{cd}	5.73 ± 1.53^{bc}
10:90 PF/BP	3.67 ± 1.80^{f}	4.67 ± 1.76^{d}	4.13 ± 1.96^{d}	4.53 ± 2.23^{c}	3.60 ± 2.10^{e}	4.20 ± 2.11^{d}
LMP	7.47 ± 1.06^{b}	6.27 ± 1.22^{bc}	5.80 ± 2.37^{bc}	5.60 ± 1.96^{bc}	5.80 ± 2.37^{ab}	6.60 ± 1.80^{b}
IMP	7.07 ± 0.96^{b}	5.40 ± 1.84^{cd}	6.07 ± 1.67^{b}	6.40 ± 1.84^{b}	6.07 ± 1.67^{ab}	6.33 ± 1.63^{b}

Mean ± standard deviation.

Mean with the same superscripts in the same column are not significantly different at 5% probability level.

Keys: **100% PF** – 100% cassava; **100% BP** – 100% breadfruits; **90:10 PF/BP** – 90% cassava co-processed with 10% breadfruits; **80:20 PF/BP** – 80% cassava co-processed with 20% breadfruits; **50:50 PF/BP** – 50% cassava co-processed with 50% breadfruits; **20:80 PF/BP** – 20% cassava co-processed with 80% breadfruits; **10:90 PF/BP** – 10% cassava co-processed with 90% breadfruits; **LMP** – Locally made *pupuru*; **IMP** – Industrially made *pupuru*

Results from this study suggest that the co-processing of cassava with breadfruit up to 50% breadfruit substitution will produce a meal that is acceptable, having a functional quality index. The abundance experienced during the breadfruit season in the south-western part of Nigeria can be exploited by utilizing breadfruit in the production of *pupuru* analogues. The value-added product can also boost the foreign earning of the country if the exportable product is exported to neighbouring countries. The local production of *pupuru* analogues is expected to be cheaper than the price per unit of *pupuru* made from cassava because breadfruit is abundant and cheaper.

4 Conclusions

The study concluded that *pupuru* analogues of acceptable sensory and physicochemical properties could be produced from cassava co-processed with breadfruit. The study provides valuable information regarding the utilization of breadfruit in food material, thereby preventing wastage of the crop during its season as well as expanding the use of breadfruit in food deficit regions.

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